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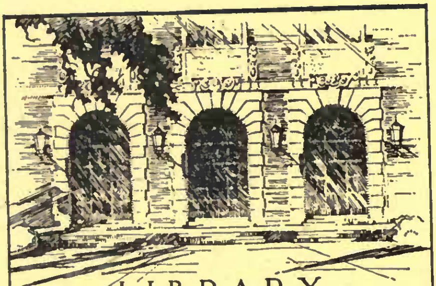

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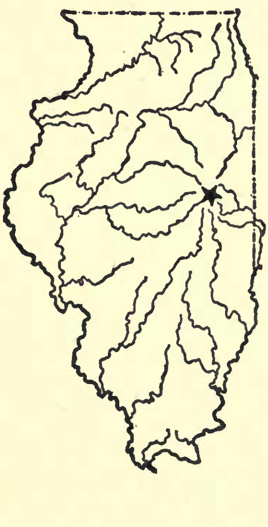
BULLETIN No. 291

A TECHNICAL STUDY OF THE DIGESTIBILITY OF CORN STOVER SILAGE FOR BEEF COWS

By T. S. Hamilton and H. P. Rusk



URBANA, ILLINOIS, MAY, 1927

THE more practical aspects of this investigation, which included a study of the digestibility of corn stover silage for beef cows and also a determination of the metabolizable energy of the silage, are as follows:

1. Apparently no considerable change in chemical composition is brought about by ensiling corn stover.

2. The availability to ruminants of the nutrients in corn stover silage is practically the same as that of the nutrients in ordinary corn stover.

3. There is about 85 percent as much total digestible nutrients in stover silage as there is in the same weight of whole corn silage; however, experimental feeding trials at this Station indicate that in practical feeding stover silage is only about two-thirds as valuable as normal silage.

4. The advantages of feeding stover silage over ordinary stover from the shock or pasturing in the fields are (1) reduction of loss of material from exposure to rain and wind; (2) no loss from tramping; (3) an increased palatability, causing a greater consumption and smaller waste in feeding due to the fact that stalks have been softened, broken up, made juicy and palatable; (4) a much greater ultimate utilization of the nutrients of the corn crop than when the stover is fed from the shock or is pastured in the field.

5. The ensiling of stover offers a method of utilizing the by-products of corn culture in an effective and economical way without limiting the utilization of the main product, the grain.

A TECHNICAL STUDY OF THE DIGESTIBILITY OF CORN STOVER SILAGE FOR BEEF COWS

By T. S. Hamilton, Associate in Animal Nutrition, and H. P. Rusk, Chief of Cattle Husbandry

Under methods of harvesting prevalent thruout much of the corn belt the stalk, leaves, and husks of the corn plant are left in the fields. The utilization of the potential feeding value of this by-product has long been a subject for study and experimentation. Pasturing in the fields is obviously wasteful and often damages the soil by causing it to puddle. Shredded stover and ordinary stover from shocked corn fail to meet the requirements fully, because large portions are woody and unpalatable, and consequently are wasted.

The production of normal corn silage from the entire corn plant probably makes possible the most complete and effective utilization. However, a demand for a method which does not limit the disposal of the grain has stimulated a revival of interest in the possibilities of silage made from the stover without the grain. Results of recent experimental feeding trials lend some encouragement for this method of utilizing the stover. These results, together with the fact that analytical studies indicate that so far as the chemical constituents are concerned the stover contains nearly one-half of the total crude protein, carbohydrates, and fat of the entire corn plant, have led to many extravagant claims regarding the nutritive value of stover silage.

The nutritive value of a feed, however, depends not only upon its chemical composition, but also upon the ability of a given class of animals to utilize the various nutrients in the combinations found in that feed. The object of this investigation, therefore, was to make possible a better understanding of the true feeding value of corn stover silage by determining not only the apparent digestibility of the nutrients, but also the metabolizable energy (energy of the feed consumed minus the energy of the solid, liquid, and gaseous excreta) of this product when fed to beef cows.

PLAN OF INVESTIGATION

The investigation was carried out during the months of January and February, 1923. The digestion stalls were located in a building which was kept fairly cool, but not cold. The experimental animals were dry, pregnant cows of beef type weighing about 1,200 pounds. These cows were taken from a group that was being wintered on a ration of stover silage and soybean oil meal, and consequently were accustomed to the experimental ration. Eight animals were used, four in each of two 15-day digestion trials. Each digestion trial consisted of a 7-day preliminary feeding period, during which the cows were fed individually the same rations which they were to receive later during the collection period, and a period in the digestion stalls of 8 days, during the last 7 days of which the collections were made.

Collections were made by attendants constantly on duty, two at a time. The feces were collected in especially constructed shovels and placed immediately in air-tight containers. The urine was collected in galvanized iron buckets made to fasten on the ends of wooden handles about 5 feet long. The urine was poured into air-tight containers immediately after collection. In order to guard against accidents in making the collections, a large shallow water-tight galvanized iron pan about 4 feet long, 3 feet wide, and 6 inches deep was placed behind each cow. Each stall was equipped with a heavy canvas pad about 3 inches thick so that the cow did not stand on the board floor of the stall. The stalls were wide enough so that the cows could lie down at will.

The ration consisted of a good grade of corn stover silage, soybean oil meal, salt, and water. The silage used during both trials was from the same silo, altho that used during the second trial was taken from a lower level. The silage was made from the stover of shock corn which had been cut and shocked at the usual time. After the ears had dried sufficiently for cribbing, the shocks were hauled to the silo, the ears removed, and the stover cut and blown into the silo, water being added thru the distributor at the rate of approximately 100 pounds per 100 pounds of stover. The same shipment of soybean oil meal served thruout both trials.

Each cow was fed all the silage she would eat. During the digestion trials this averaged nearly 50 pounds of fresh silage daily.[1] The daily allowance of soybean oil meal was 1 pound per cow. The cows were fed twice daily: in the morning (just after the feces and urine had been aliquoted), and in the evening. Half the daily ration was given at each feeding. The soybean oil meal was sprinkled over the silage. After the first 5 days of the first trial 1 ounce of salt was regularly added to the morning feed. Water was offered from a pail twice daily, once before the morning feed and again before the evening feed.

METHOD OF SAMPLING

The urine and feces were aliquoted daily, about 8:30 o'clock each morning. Each day's excretion of urine and feces from each cow was

[1]During the entire winter the average daily consumption of the lot of ten cows from which the group was taken was 66.53 pounds of stover silage and 1 pound of soybean oil meal.

separately weighed, mixed, and aliquoted. The aliquots taken thruout the tests were one-tenth the daily excretion. The urine was mixed by shaking and stirring, while the feces were mixed and quartered down in a large shallow pan with the aid of a bricklayer's hand trowel. The feces were of such consistency that this method of mixing proved very satisfactory. The aliquoting was done in a cool room and as quickly as possible so that the loss in moisture during this procedure was certainly very small. The daily aliquots from each animal were placed in air-tight containers and kept at about freezing temperature. Each succeeding daily aliquot was added to the preceding one until the end of the collection period, when they were carefully composited and analyzed. The feces were analyzed in the fresh condition. The orts remaining in the manger each morning were weighed and immediately air-dried.

The silage was taken from the silo each morning and brought to the digestion room in large canvas bags in time for the morning feeding. It was then mixed and the daily ration was weighed out. The evening allowance was placed in 50-pound lard cans which were tightly covered. While the silage was being weighed out for the day's feed, an occasional handful was placed in a pail for analysis. Exactly 1 kilogram of silage was taken in this manner each morning for analysis. This sample was taken immediately to the laboratory in a tightly covered pail and quickly air-dried at about 65°C. The daily air-dried samples were combined to form a composite sample for the collection period. The orts from each animal were treated in exactly the same manner. Only one sample of soybean oil meal was analyzed, and this was taken by placing a handful of the meal in a pail each morning at the time the feed was being weighed out.

RESULTS OF EXPERIMENTS

The average weight of the four cows in the first trial was 1,255 pounds at the beginning of the preliminary period, 1,250 pounds at the beginning of the collection period, 1,194 pounds at the end of the trial, and 1,279 pounds two weeks later; thus, the average loss in weight while in the stalls was 56 pounds (Table A, Appendix). The same data for the four cows in the second trial are 1,141 pounds at the start, 1,109 when placed in the digestion stalls, and 1,084 at the end of the trial, the average loss in weight being 25 pounds. One week after their return to the feed lot these cows averaged 1,145 pounds in weight. The nitrogen balance data (Table D of the Appendix) indicate that there was some loss in body flesh, tho, because of the immediate return of each cow to her original weight within one or two weeks after termination of the experiment,[1] most of the loss in weight was certainly loss in *fill.*

The percentage composition of the soybean oil meal and of the corn stover silage used during the two collection periods is given in Table 1. The silage used during the first period was taken from the

TABLE 1.—PERCENTAGE COMPOSITION AND GROSS ENERGY OF FEEDS

Feed	Dry substance	Crude protein	N-free extract	Crude fiber	Ether extract	Crude ash	Gross energy per 100 pounds
							therms
Corn stover silage, Period I	28.41	1.81	14.13	9.38	.53	2.56	54.9
Corn stover silage, Period II	25.03	1.65	12.65	8.02	.50	2.21	48.4
Soybean oil meal	90.63	39.95	36.18	6.73	5.07	6.59	197.8

TABLE 2.—PERCENTAGE COMPOSITION AND GROSS ENERGY OF ORTS, FECES, AND URINE

Cow No.	Sample	Dry substance	Crude protein[a]	N-free extract	Crude fiber	Ether extract	Crude ash	Gross energy per 100 pounds
				Period I				
								therms
1	Orts	28.84	1.25	12.34	9.41	.39	1.45	50.5
	Feces	16.35	1.62	7.14	4.00	.24	3.35	32.1
	Urine	.....	(.73)	.....	.....	.....	.....	8.3
2	Orts	26.61	1.67	13.40	9.10	.43	2.01	52.3
	Feces	13.27	1.21	6.67	3.06	.21	2.12	25.5
	Urine	.....	(.74)	.....	.....	.....	.....	6.8
3	Orts	28.67	1.89	14.26	9.76	.51	2.25	56.4
	Feces	13.82	1.44	5.94	3.16	.23	3.05	28.3
	Urine	.....	(.78)	.....	.....	.....	.....	8.6
4	Orts	24.29	1.55	12.24	8.24	.39	1.87	48.0
	Feces	15.38	1.40	6.66	3.78	.29	3.25	29.9
	Urine	.....	(.81)	.....	.....	.....	.....	8.6
				Period II				
5	Orts	34.36	2.30	18.04	10.86	.65	2.51	65.6
	Feces	14.76	1.40	7.46	3.52	.25	2.13	26.4
	Urine	.....	(.60)	.....	.....	.....	.....	7.6
6	Orts	27.23	1.44	13.31	10.29	.35	1.84	53.0
	Feces	12.92	1.23	6.28	3.17	.28	1.96	23.0
	Urine	.....	(.75)	.....	.....	.....	.....	7.8
7	Orts	25.41	1.72	12.74	8.55	.47	1.93	49.4
	Feces	15.43	1.35	7.64	3.71	.36	2.37	28.8
	Urine	.....	(.69)	.....	.....	.....	.....	10.0
8	Orts	35.09	1.80	16.55	14.22	.41	2.11	69.2
	Feces	13.81	1.27	6.87	3.29	.24	2.14	25.4
	Urine	.....	(.74)	.....	.....	.....	.....	7.6

[a]In case of urine samples the figures in this column represent the percentage of total nitrogen instead of crude protein.

[1]The lot of ten cows from which these eight test cows were taken averaged 1,055.5 pounds when started on this ration, November 1, 1922, and 1,159 pounds at the end of the winter trial, March 21, 1923. The average total gain per head was 103.5 pounds, or an average daily gain of .742 pound, for the 139.5 days, including time spent in the digestion trials.

upper part of the silo, and that used during the second period was taken from a lower level in the silo.

The percentage composition of the orts, the fresh feces, and the urine is given in Table 2. In addition to the regular routine chemical determinations, the gross energy of all samples was regularly determined in a bomb calorimeter.

TABLE 3.—AMOUNTS OF FEED OFFERED AND WATER CONSUMED, AND WEIGHT OF ORTS, FECES, AND URINE

Cow No.	Feed offered			Water consumed	Orts	Feces	Urine
	Stover silage	Soybean meal	Salt				
				Period I			
	lbs.	*lbs.*	*oz.*	*lbs.*	*lbs.*	*lbs.*	*lbs.*
1..............	350	7	2	146.87	4.04	261.49	107.27
2..............	320	7	2	228.56	24.32	301.79	132.78
3..............	300	7	2	191.94	53.98	238.28	82.15
4..............	320	7	2	139.81	19.55	236.39	102.83
				Period II			
5..............	350	7	7	172.87	3.09	285.99	100.77
6..............	350	7	7	208.75	4.42	334.07	97.42
7..............	350	7	7	113.56	25.03	237.25	100.90
8..............	350	7	7	172.25	1.20	289.97	116.80

The total weights of feed offered, water consumed, orts left, and feces and urine excreted during the two 7-day collection periods are given in Table 3.

DIGESTIBILITY OF CORN STOVER SILAGE

All the data relative to the calculation of the coefficients of digestibility of the nutrients in the combined ration of corn stover silage and soybean oil meal, when fed in the ratio of approximately 1 to 50, are given in Table 4. The calculations were made in the usual manner and the table is self-explanatory.

The calculations of the coefficients of digestibility of the nutrients in the corn stover silage alone are presented in Table 5. The correction for the soybean oil meal in the ration was made in the usual manner, using coefficients of digestibility for soybean oil meal obtained at this Station on sheep.[1] The nutrients in the orts are assumed to be derived entirely from the corn stover silage. Therefore the nutrients consumed from the silage are calculated by subtracting the nutrients in the orts from the corresponding nutrients in the silage fed. The above assumption is made because of the small quantity of soybean oil meal in the ration, and because the orts remaining in the manger were usually

[1]Unpublished data from an experiment on the digestibility of soybean products with sheep at the University of Illinois.

TABLE 4A.—DIGESTIBILITY OF THE COMBINED RATION OF CORN STOVER SILAGE AND SOYBEAN OIL MEAL: PERIOD I

(Amounts in pounds)

	Dry substance	Crude protein	N-free extract	Crude fiber	Ether extract
Cow No. 1					
Silage fed, 350 pounds	99.4	6.3	49.4	32.8	1.8
Soybean oil meal fed, 7 pounds	6.3	2.8	2.5	.5	.4
Total ration	105.7	9.1	51.9	33.3	2.2
Orts, 4.04 pounds	1.0	.1	.5	.4	.0
Nutrients consumed	104.7	9.0	51.4	32.9	2.2
Feces, 261.49 pounds	42.7	4.2	18.7	10.5	.6
Nutrients digested	62.0	4.8	32.7	22.4	1.5
Percentage digested	(59.2)	(53.3)	(63.6)	(68.1)	(68.2)
Cow No. 2					
Silage fed, 320.0 pounds	90.9	5.8	45.2	30.0	1.7
Soybean oil meal fed, 7 pounds	6.3	2.8	2.5	.5	.4
Total ration	97.2	8.6	47.7	30.5	2.1
Orts, 24.32 pounds	6.5	.4	3.3	2.2	.1
Nutrients consumed	90.7	8.2	44.4	28.3	2.0
Feces, 301.79 pounds	40.0	3.6	20.1	9.2	.6
Nutrients digested	50.7	4.6	24.3	19.1	1.4
Percentage digested	(55.9)	(56.1)	(54.7)	(67.5)	(70.0)
Cow No. 3					
Silage fed, 300 pounds	85.2	5.4	42.4	28.1	1.6
Soybean oil meal fed, 7 pounds	6.3	2.8	2.5	.5	.4
Total ration	91.5	8.2	44.9	28.6	2.0
Orts, 53.98 pounds	15.5	1.0	7.7	5.3	.3
Nutrients consumed	76.0	7.2	37.2	23.3	1.7
Feces, 238.28 pounds	32.9	3.4	14.2	7.5	.6
Nutrients digested	43.1	3.8	23.0	15.8	1.1
Percentage digested	(56.7)	(52.8)	(61.8)	(67.8)	(64.7)
Cow No. 4					
Silage fed, 320 pounds	90.9	5.8	45.2	30.0	1.7
Soybean oil meal fed, 7 pounds	6.3	2.8	2.5	.5	.4
Total ration	97.2	8.6	47.7	30.5	2.1
Orts, 19.55 pounds	4.7	.3	2.4	1.6	.1
Nutrients consumed	92.5	8.3	45.3	28.9	2.0
Feces, 236.39 pounds	36.4	3.3	15.7	8.9	.7
Nutrients digested	56.1	5.0	29.6	20.0	1.3
Percentage digested	(60.6)	(60.2)	(65.4)	(69.2)	(65.0)

the larger, most unpalatable pieces of the stalk with no visible quantity of oil meal. The coefficients of digestibility of the soybean oil meal, taken from the average figures obtained on twelve sheep, are as follows: dry substance, 98 percent; crude protein, 88 percent; N-free extract, 100 percent; ether extract, 95 percent; and crude fiber, 60 percent.

A summary of the coefficients of digestibility of the nutrients in the combined ration calculated in Table 4 is given in Table 6, while Table 7 gives the summary of the coefficients of digestibility of the corn stover silage alone as calculated in Table 5.

A noticeable effect of the correction for the soybean oil meal is in the lowering of the apparent digestibility of the crude protein of the combined rations from an average percentage of 55.6 to 39. Also, the digestibility of the ether extract was lowered from an average of 65.7 percent for the combined ration to an average of 59.2 percent for the silage alone. The total amount of ether extract in the silage, how-

TABLE 4B.—DIGESTIBILITY OF THE COMBINED RATION OF CORN STOVER SILAGE AND SOYBEAN OIL MEAL: PERIOD II
(Amounts in pounds)

	Dry substance	Crude protein	N-free extract	Crude fiber	Ether extract
Cow No. 5					
Silage fed, 350 pounds	87.6	5.8	44.3	28.1	1.8
Soybean oil meal fed, 7 pounds	6.3	2.8	2.5	.5	.4
Total ration	93.9	8.6	46.8	28.6	2.2
Orts, 3.09 pounds	1.1	.1	.5	.3	.0
Nutrients consumed	92.8	8.5	46.3	28.3	2.2
Feces, 285.99 pounds	42.2	4.0	21.3	10.1	.7
Nutrients digested	50.6	4.5	25.0	18.2	1.5
Percentage digested	(54.5)	(52.9)	(54.0)	(64.3)	(68.2)
Cow No. 6					
Silage fed, 350 pounds	87.6	5.8	44.3	28.1	1.8
Soybean oil meal fed, 7 pounds	6.3	2.8	2.5	.5	.4
Total ration	93.9	8.6	46.8	28.6	2.2
Orts, 4.42 pounds	1.2	.1	.6	.4	.0
Nutrients consumed	92.7	8.5	46.2	28.2	2.2
Feces, 334.07 pounds	43.2	4.1	21.0	10.6	.9
Nutrients digested	49.5	4.4	25.2	17.6	1.3
Percentage digested	(53.4)	(51.8)	(54.5)	(62.4)	(59.1)
Cow No. 7					
Silage fed, 350 pounds	87.6	5.8	44.3	28.1	1.8
Soybean oil meal fed, 7 pounds	6.3	2.8	2.5	.5	.4
Total ration	93.9	8.6	46.8	28.6	2.2
Orts, 25.03 pounds	6.4	.4	3.2	2.1	.1
Nutrients consumed	87.5	8.2	43.6	26.5	2.1
Feces, 237.25 pounds	36.6	3.2	18.1	8.8	.8
Nutrients digested	50.9	5.0	25.5	17.7	1.3
Percentage digested	(58.2)	(61.0)	(58.5)	(66.8)	(61.9)
Cow No. 8					
Silage fed, 350 pounds	87.6	5.8	44.3	28.1	1.8
Soybean oil meal fed, 7 pounds	6.3	2.8	2.5	.5	.4
Total ration	93.9	8.6	46.8	28.6	2.2
Orts, 1.20 pounds	.4	.0	.2	.2	.0
Nutrients consumed	93.5	8.6	46.6	28.4	2.2
Feces, 289.97 pounds	40.0	3.7	19.9	9.4	.7
Nutrients digested	53.5	4.9	26.7	18.9	1.5
Percentage digested	(57.2)	(57.0)	(57.2)	(66.5)	(68.2)

ever, is so small in comparison with the other nutrients that this apparent decrease in digestibility of ether extract need not be considered. The other nutrients are little affected.

The average percentages of digestible nutrients in the corn stover silage are tabulated in Table 8.

PREVIOUS INVESTIGATIONS INDICATE BETTER UTILIZATION OF CORN ROUGHAGES BY CATTLE THAN BY SHEEP

The digestibility of corn stover silage has been determined by Tangl and Weiser.[1] Using wethers as experimental animals, these investigators determined, in duplicate, the digestibility of stover silage taken at three different levels from a reinforced concrete silo. A comparison of the average digestion coefficients obtained by Tangl and Weiser, and those obtained in this investigation, is given in Table 9. This comparison shows a fairly close agreement between the values obtained in the two investigations, in all the nutrients except crude

TABLE 5.—CALCULATION OF DIGESTIBILITY OF CORN STOVER SILAGE
(Amounts in pounds)

	Dry substance	Crude protein	N-free extract	Crude fiber	Ether extract
Period I					
Cow No. 1.					
Nutrients consumed, silage	98.4	6.3	48.9	32.4	1.8
Nutrients digested					
Total	62.0	4.8	32.7	22.4	1.5
Soybean oil meal	6.2	2.5	2.5	.3	.3
Silage	55.8	2.3	30.2	22.1	1.2
Coefficient of digestibility for silage	(57)	(37)	(62)	(68)	(67)
Cow No. 2					
Nutrients consumed, silage	84.4	5.4	41.9	27.8	1.6
Nutrients digested					
Total	50.7	4.6	24.3	19.1	1.3
Soybean oil meal	6.2	2.5	2.5	.3	.3
Silage	44.5	2.1	21.8	18.8	1.0
Coefficient of digestibility for silage	(53)	(39)	(52)	(68)	(63)
Cow No. 3					
Nutrients consumed, silage	69.7	4.4	34.7	22.8	1.3
Nutrients digested					
Total	43.1	3.8	23.0	15.8	1.1
Soybean oil meal	6.2	2.5	2.5	.3	.3
Silage	36.9	1.3	20.5	15.5	.8
Coefficient of digestibility for silage	(53)	(30)	(59)	(68)	(61)
Cow No. 4					
Nutrients consumed, silage	86.2	5.5	42.8	28.4	1.6
Nutrients digested					
Total	56.1	5.0	29.6	20.0	1.3
Soybean oil meal	6.2	2.5	2.5	.3	.3
Silage	49.9	2.5	27.1	19.7	1.0
Coefficient of digestibility for silage	(58)	(45)	(63)	(69)	(63)
Period II					
Cow No. 5					
Nutrients consumed, silage	86.5	5.7	43.8	27.8	1.7
Nutrients digested					
Total	50.6	4.5	25.0	18.2	1.4
Soybean oil meal	6.2	2.5	2.5	.3	.3
Silage	44.4	2.0	22.5	17.9	1.1
Coefficient of digestibility for silage	(51)	(35)	(51)	(64)	(65)
Cow No. 6					
Nutrients consumed, silage	86.4	5.7	43.7	27.7	1.7
Nutrients digested					
Total	49.5	4.4	25.2	17.6	1.1
Soybean oil meal	6.2	2.5	2.5	.3	.3
Silage	43.3	1.9	22.7	17.3	.8
Coefficient of digestibility for silage	(50)	(33)	(52)	(62)	(47)
Cow No. 7					
Nutrients consumed, silage	81.2	5.4	41.1	26.0	1.6
Nutrients digested					
Total	50.9	5.0	25.5	17.7	1.1
Soybean oil meal	6.2	2.5	2.5	.3	.3
Silage	44.7	2.5	23.0	17.4	.8
Coefficient of digestibility for silage	(55)	(46)	(56)	(67)	(50)
Cow No. 8					
Nutrients consumed, silage	87.2	5.8	44.1	27.9	1.8
Nutrients digested					
Total	53.5	4.9	26.7	18.9	1.4
Soybean oil meal	6.2	2.5	2.5	.3	.3
Silage	47.3	2.4	24.2	18.6	1.1
Coefficient of digestibility for silage	(54)	(41)	(55)	(67)	(61)

fiber and crude fat. The digestibility of the crude fiber of corn stover silage obtained by Hamilton and Rusk on cattle was 66.7 percent, as compared with 57.8 percent obtained by Tangl and Weiser on sheep. It is a noticeable fact that the differences in the coefficients obtained in the two investigations are all in favor of the cattle, except the co-

TABLE 6.—SUMMARY OF COEFFICIENTS OF DIGESTIBILITY OF THE COMBINED RATION OF CORN STOVER SILAGE AND SOYBEAN OIL MEAL

Cow No.	Dry substance	Crude protein	N-free extract	Crude fiber	Ether extract
Period I					
1	59	53	64	68	68
2	56	56	55	68	70
3	57	53	62	68	65
4	61	60	65	69	65
Average	58.2	55.5	61.5	68.3	67.0
Period II					
5	55	53	54	64	68
6	53	52	55	62	59
7	58	61	59	67	62
8	57	57	57	67	68
Average	55.8	55.8	56.3	65	64.3
Average for Periods I and II	57.0	55.6	58.9	66.6	65.7

efficients for crude fat, which have little significance because of the small amount of ether extract in corn stover silage.

The question whether or not different genera of ruminants digest roughages with the same efficiency has not been satisfactorily answered. Investigations comparing the digestive powers of cattle and sheep for the same feed are not numerous, and the evidence obtained in the majority of these is unsatisfactory in view of the use of only one or two animals. A cursory glance at the results of almost any digestion trial in which two or more animals are used will show that considerable differences in digestion coefficients occur between individual animals of the same kind.

Bartlett[2] has carried out a series of digestion experiments with sheep and steers in which he compared the digestibility of seventeen different rations by sheep and by steers. Of the seventeen rations, eight were roughages or largely roughages and the remainder were concentrates or largely concentrates. The average coefficients of digestibility for the dry substance, crude protein, and crude fiber of the eight roughages were determined to be as follows:

	By steers	*By sheep*	*Difference in favor of steers*
Dry substance	61.6	58.3	+3.3
Crude protein	49.5	50.3	— .8
Crude fiber	61.2	55.1	+6.1

Bartlett concluded that the steers used in his experiments "had a greater capacity for digesting coarse fodders low in protein, like timothy hay and corn fodders, than sheep," and the above figures, especially, indicate that this is true. He further states: "It is evident from

TABLE 7.—SUMMARY OF COEFFICIENTS OF DIGESTIBILITY OF CORN STOVER SILAGE

Cow No.	Dry substance	Crude protein	N-free extract	Crude fiber	Ether extract
			Period I		
1	57	37	62	68	67
2	53	39	52	68	63
3	53	30	59	68	61
4	58	45	63	69	63
Average	55.3	37.8	59.0	68.3	63.5
			Period II		
5	51	35	51	64	65
6	50	33	52	62	47
7	55	46	56	67	50
8	54	41	55	67	61
Average	52.5	38.5	53.5	65.0	55.8
Average for Periods I and II	53.9	38.2	56.3	66.7	59.2
Coefficients of digestibility for combined ration	57.0	55.6	58.9	66.6	65.7

TABLE 8.—PERCENTAGES OF DIGESTIBLE NUTRIENTS IN CORN STOVER SILAGE

	Dry substance	Crude protein	N-free extract	Crude fiber	Ether extract
Period I	15.7	.68	8.3	6.4	.34
Period II	13.2	.64	6.7	5.2	.28
Average[a]	14.5	.66	7.6	5.8	.31

[a]The average percentage of dry substance in the two samples of silage used was 26.72.

TABLE 9.—COMPARISON OF COEFFICIENTS OF DIGESTIBILITY OF CORN STOVER SILAGE OBTAINED BY DIFFERENT INVESTIGATORS

	Hamilton and Rusk (with cattle)	Tangl and Weiser (with sheep)	Difference in favor of cattle
Dry substance	53.9	51.2	2.7
Crude protein	38.2	32.9	5.6
N-free extract	56.3	56.2	.1
Crude fiber	66.7	57.8	8.9
Crude fat	59.2	68.1	—8.9

a study of these results and others before published that as great differences in digestion coefficients will occur between sheep, individually, as is likely to occur between sheep and steers."

Jordan and Hall[3] made a compilation of the results of American digestion experiments up to 1898, and concluded that "American experiments neither confirm nor disprove the general assumption of German experimenters that the different genera of ruminants digest coarse fodders with practically the same efficiency."

In discussing this question Armsby[4] states: ". . . . it would appear that in the case of the coarser and less digestible forms of forage a distinct difference exists in favor of cattle." The evidence, showing a greater utilization of the nutrients, especially the crude fiber, of the coarser roughages by cattle, is much more consistent for the roughages derived from the corn plant than for the hays.

In Table 10 are given the results of experiments as reported by several investigators comparing the digestibility of the same kind of roughage from the corn plant by cattle and by sheep. It is to be regretted that a larger number of animals was not used in these comparative experiments.

TABLE 10.—COMPARISON OF DIGESTIBILITY OF THE SAME KINDS OF FEED BY STEERS AND BY SHEEP

	Coefficients of digestibility					Investigator and reference
	Dry substance	Crude protein	N-free extract	Crude fiber	Ether extract	
Corn silage						
1 steer	68.1	44.0	69.7	77.6	76.6	Frear[5]
2 sheep	53.8	21.5	54.9	63.6	68.3	
Diff. in favor of steers	14.3	22.5	14.8	14.0	8.3	
Corn silage						
3 steers	75.6	65.0	75.3	81.9	89.5	Armsby[6]
2 sheep	66.4	56.0	68.6	70.6	88.5	
Diff. in favor of steers	9.2	9.0	6.7	11.3	1.0	
Leaming corn silage						
2 steers	63.1	46.7	64.1	67.2	68.3	Bartlett[2]
2 sheep	60.0	50.9	65.0	57.8	75.5	
Diff. in favor of steers	3.1	—4.2	—.9	9.4	—7.2	
Corn fodder (Sanford corn)						
2 steers	72.9	56.9	74.4	79.8	72.3	Bartlett[2]
2 sheep	64.9	46.7	68.2	69.9	59.3	
Diff. in favor of steers	8.0	10.2	6.2	9.9	13.0	
Corn fodder						
2 steers	67.4	58.6	66.8	74.4	79.2	Armsby[6]
1 sheep	62.5	55.8	61.6	68.1	77.8	
Diff. in favor of steers	4.9	2.8	5.2	6.3	1.4	

These direct comparisons and the less direct comparison made in Table 9 all indicate consistently better utilization by cattle than by sheep of the nutrients from the roughages derived from the corn plant. While the evidence is not sufficient to warrant a definite conclusion, it is quite probable that cattle do digest roughages from the corn plant better than do sheep. If this is true, it is also reasonable to suppose that the same is true of all coarse roughages low in protein, altho the available evidence on this point is less conclusive.

In their investigation Tangl and Weiser also determined the digestibility of ordinary dry corn stover (averaging 85.0 percent dry substance) with sheep. A comparison of the coefficients of digestibility of corn stover and corn stover silage is made by these authors, and a table given by them is copied in slightly different form in Table 11 of this bulletin. These data show no difference in the digestibility of dry substance, a difference in favor of the dry corn stover of 3.4 percent in the digestibility of the crude protein, and of 2.8 percent in that of the nitrogen-free extract, and a difference in favor of the silage of

TABLE 11.—COMPARISON OF COEFFICIENTS OF DIGESTIBILITY OF CORN STOVER AND CORN STOVER SILAGE[a]

	Digestibility of—		Difference in favor of—	
	Corn stover silage	Corn stover	Corn stover	Corn stover silage
Dry substance	51.2	51.2	0	0
Crude protein	32.9	36.3	3.4	....
N-free extract	56.2	59.0	2.8	....
Crude fiber	57.8	53.5	....	4.3
Crude fat	68.1	58.3	....	9.8

[a]From Tangl and Weiser (*loc. cit.*).

4.3 percent for crude fiber, and 9.8 percent for crude fat. These differences are small, and when the total dry substance consumed from both feeds is found to have averaged only 520 grams of corn stover daily per head, and the corn stover silage 528 grams, the differences are insignificant.

TABLE 12.—PERCENTAGE COMPOSITION AND PERCENTAGE OF DIGESTIBLE NUTRIENTS IN WHOLE CORN SILAGE, CORN STOVER, AND CORN STOVER SILAGE

	Composition					
	Fresh			Dry matter in—		
	Whole corn silage[a]	Corn stover silage[b]	Corn stover[c] (field)	Whole corn silage[a]	Corn stover silage[b]	Corn stover[c] (field)
Dry substance	20.0	26.7	60.0	100	100	100
Crude protein	1.7	1.7	4.6	8.5	6.4	7.7
N-free extract	11.1	13.4	30.1	55.5	50.1	50.2
Crude fiber	5.4	8.7	20.6	27.0	32.6	34.3
Crude fat	.7	.5	.8	3.5	1.9	1.3
Crude ash	1.1	2.4	3.9	5.5	9.0	6.5
	Digestible nutrients					
Crude protein	.9	.7	1.7	4.5	2.6	2.8
N-free extract	7.7	7.6	17.8	38.5	28.4	29.7
Crude fiber	3.5	5.8	13.2	17.5	21.7	22.0
Crude fat	.5	.3	.6	2.5	1.4	.9

[a]Lindsey, Haskins, Smith, and Beals (*loc. cit.*), average of 50 analyses.
[b]Hamilton and Rusk.
[c]Lindsey, Haskins, Smith, and Beals (*loc. cit.*), average of 47 analyses.

The composition and percentage of digestible nutrients of whole corn silage, corn stover, and corn stover silage are given in Table 12. The data concerning the whole corn silage and corn stover are taken from the compilation by Lindsey, Haskins, Smith, and Beals,[7] and that for the corn stover silage from the present investigation.

STOVER SILAGE ABOUT TWO-THIRDS AS VALUABLE AS WHOLE CORN SILAGE

It is evident from the data in Table 12 that there is no great change in chemical composition brought about by ensiling corn stover, and further that the availability of the nutrients to ruminants is practically the same. The increased palatability of the silage, the consequent smaller waste in feeding, and the fact that there is no loss of material from exposure to rain and wind, insure a much greater ultimate utilization of the nutrients of the corn crop when the stover is put in the silo than when it is left in the field. A comparison of the nutrients available in the stover silage with those in the whole corn silage shows about 85 percent as much total digestible nutrients in the stover silage as in the same weight of whole corn silage. However, extensive feeding trials at this Station indicate that in practical feeding stover silage is only about two-thirds as valuable as normal silage, pound for pound on fresh basis.

METABOLIZABLE ENERGY OF CORN STOVER SILAGE

In addition to the regular routine analyses, the gross energy of the feed, orts, feces, and urine was determined by means of a calorimetric bomb. The metabolizable energy was computed by deducting from the gross energy of the feed consumed the energy of the feces, urine, and methane.

The simple digestion apparatus used for these experiments was not provided with means for measuring the methane produced, so the energy loss due to this gas had to be calculated. Armsby has shown that an average of 4.5 grams of methane are produced for every 100 grams of carbohydrates digested by a ruminant.[8] For the heat of combustion of methane Armsby[9] uses the figure 13.344 large calories per gram. Thus to calculate the energy loss due to gaseous fermentation for an animal during a collection period, the sum of the weights in grams of the nitrogen-free extract and crude fiber digested during the period, divided by 100 and multiplied by 4.5, gives the weight in grams of methane produced. The weight in grams of methane produced multiplied by 13.34 gives the energy content of the methane in calories. This represents a loss of energy to the animal, and is deducted from the energy of the feed.

Table B of the Appendix gives, for each cow, the total dry substance, total nitrogen, and gross energy of the feed consumed, and of the feces excreted; the total digestible carbohydrates, their methane equivalent in grams and in therms of energy; the total digestible organic nutrients; and the nitrogen and energy of the urine.

An accurate computation of the metabolizable energy of a feed or ration must involve a correction for the nitrogen gained or lost by the animal. If the animal is losing nitrogen during the period, it must be recognized that part of the energy of the urine has originated from partially oxidized body protein. According to Rubner[10] the potential energy of the urine is increased by about 7.45 calories for each gram of urinary nitrogen coming from the oxidation of body protein. Therefore, in case of a negative nitrogen balance, indicating that body protein is being broken down, for each gram of nitrogen in the urine above that derived from the feed, equal to the negative nitrogen balance, 7.45 calories must be subtracted from the gross energy of the urine. On the other hand, when nitrogen is being stored in the body, as indicated by a positive nitrogen balance, 7.45 calories must be added to the gross energy of the urine for each gram of nitrogen stored, since this amount of metabolizable energy is being retained in the body. For example, Cow No. 1 had a negative nitrogen balance of 50 grams for the whole period. Therefore 50 times 7.45 calories, or 372.5 calories must be subtracted from the gross energy of the urine to give the metabolizable energy due to the feed alone. Cow No. 5 showed a positive balance of 53 grams of nitrogen, so that 394.9 calories are added to the gross energy of the urine.

Table D of the Appendix gives the nitrogen balances of the cows. Table E shows the calculation of the metabolizable energy.

The metabolizable energy calculated as described above, of course gives the metabolizable energy for the ration as fed, which included one pound of soybean oil meal. In order to correct for this small quantity of concentrate, and to secure the metabolizable energy derived from the corn stover silage alone, figures suggested by Professor Armsby are again used. According to Armsby[11] the metabolizable energy per pound of digestible organic matter in oil meals and concentrates high in protein is between 1.996 and 2.177 therms for ruminants. The average of these two figures is 2.087 therms. The total digestible organic matter furnished by the soybean oil meal was 5.63 pounds to each cow: 5.63 multiplied by 2.087 gives 11.75 therms of metabolizable energy obtained from the ingestion of the soybean oil meal. Therefore, subtracting 11.75 therms from the total metabolizable energy in the combined ration for each cow gives the metabolizable energy derived from the corn stover silage alone.

The metabolizable energy of the combined ration and of the corn stover silage alone is given in Table 13.

The average metabolizable energy for corn stover silage alone is 1.57 therms per pound of digestible organic matter in the silage (Table

TABLE 13.—METABOLIZABLE ENERGY: SUMMARY
(Therms)

Cow No.	Metabolizable energy of combined ration: Total	Per kilogram dry substance consumed	Per pound digestible organic matter	Metabolizable energy of corn stover silage alone: Total	Per kilogram dry substance consumed	Per pound digestible organic matter
Period I						
1	96.5	2.03	1.57	84.75	1.90	1.52
2	79.9	1.94	1.62	68.15	1.78	1.56
3	63.1	1.83	1.44	51.35	1.62	1.35
4	87.2	2.08	1.56	75.45	1.93	1.50
Average	....	1.97	1.55	.....	1.81	1.48
Period II						
5	85.8	2.04	1.75	74.05	1.88	1.70
6	85.0	2.02	1.76	73.25	1.87	1.71
7	80.3	2.02	1.63	68.55	1.86	1.57
8	87.8	2.07	1.69	76.05	1.92	1.64
Average	....	2.04	1.71		1.88	1.66
Average for Periods I and II		2.00	1.63	.....	1.85	1.57

13). Armsby[11] gives the figure 1.588 therms of metabolizable energy per pound of digestible organic matter obtained from roughages in general by ruminants.

SUMMARY

The average coefficients of digestibility of corn stover silage fed to eight beef cows were found to be as follows: dry substance, 54 percent; crude protein, 38 percent; nitrogen-free extract, 56 percent; crude fiber, 67 percent; and ether extract, 59 percent.

The metabolizable energy of corn stover silage was found to vary for the eight cows from 1.35 to 1.71, with an average of 1.57 therms per pound of digestible organic matter. This value agrees almost exactly with Armsby's[11] figure of 1.588 therms per pound of digestible matter obtained from roughages for ruminants.

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APPENDIX

TABLE A.—WEIGHTS OF ANIMALS DURING DIGESTION TRIALS
(All weights in pounds)

Cow No.	Weight at beginning of digestion trial	Weight when placed in digestion stall	Weight at end of digestion trial	Loss in weight while in digestion stall	Weight one week after end of trial	Weight two weeks after end of trial
			Period I			
1	1 270	1 290	1 215	75	....	1 320
2	1 315	1 310	1 220	90	....	1 335
3	1 150	1 140	1 110	30	....	1 160
4	1 285	1 260	1 230	30	....	1 300
Average	1 255	1 250	1 194	56	....	1 279
			Period II			
5	1 135	1 130	1 100	30	1 120	.....
6	1 135	1 110	1 080	30	1 155	.....
7	1 035	1 015	990	25	1 060	.....
8	1 260	1 180	1 165	15	1 245	.....
Average	1 141	1 109	1 084	25	1 145	.....

TABLE B.—NITROGEN AND ENERGY TABLE

Cow No.	Feed consumed			Dig. carbohydrates			Digestible organic nutrients	Feces			Urine	
	Total dry substance	Total nitrogen	Energy	Total	Methane equivalent			Dry substance	Total nitrogen	Energy	Total nitrogen	Energy
	kg.	*gm.*	*therms*	*kg.*	*gm.*	*therms*	*lbs.*	*kg.*	*gms.*	*therms*	*gm.*	*therms*
						Period I						
1	47.5	612	203.9	25.0	1 125	15.0	61.4	19.4	.307	83.9	355	8.9
2	41.1	594	176.8	19.7	887	11.8	49.3	18.1	.261	76.9	446	9.0
3	34.5	522	148.1	17.6	792	10.6	43.7	14.9	.247	67.4	291	7.1
4	42.0	603	180.1	22.5	1 013	13.5	55.9	16.5	.239	70.7	378	8.8
						Period II						
5	42.1	617	181.2	19.6	882	11.8	49.1	19.1	.290	75.5	274	7.7
6	42.0	621	180.9	19.4	873	11.6	48.4	19.6	.298	76.8	332	7.6
7	39.7	594	170.8	19.6	882	11.8	49.3	16.6	.232	68.3	316	10.1
8	42.4	621	182.4	20.7	932	12.4	51.9	18.1	.267	73.6	392	8.9

TABLE C.—DAILY COLLECTION DATA: PERIOD I

Day	Feed offered: Silage lbs.	Feed offered: Soybean oil meal lbs.	Feed offered: Salt oz.	Feed offered: Water lbs.	Orts lbs.	Feces lbs.	Urine lbs.
Cow No. 1							
1	50	1	0	.13	.38	32.75	22.63
2	50	1	0	9.25	.56	30.19	11.46
3	50	1	0	24.25	.69	35.71	13.17
4	50	1	0	28.00	1.00	41.50	12.14
5	50	1	0	36.63	.76	42.40	17.13
6	50	1	1	24.13	.40	39.66	11.36
7	50	1	1	24.50	.25	39.28	19.38
Total	350	7	2	146.89	4.04	261.49	107.27
Daily average	50	1	.28	20.98	.58	37.35	15.32
Cow No. 2							
1	50	1	0	24.69	8.06	32.56	15.69
2	45	1	0	11.69	7.75	39.13	15.88
3	45	1	0	41.88	2.13	42.78	17.16
4	45	1	0	38.44	2.75	47.77	22.34
5	45	1	0	47.19	1.31	48.98	19.72
6	45	1	1	35.50	1.09	43.49	23.22
7	45	1	1	29.19	1.23	47.08	18.77
Total	320	7	2	228.58	24.32	301.79	132.78
Daily average	45.7	1	.28	32.67	3.47	43.11	18.97
Cow No. 3							
1	50	1	0	17.94	13.25	36.63	12.87
2	45	1	0	24.19	11.75	34.50	7.13
3	45	1	0	35.63	9.18	32.86	17.25
4	40	1	0	29.31	5.50	35.43	6.81
5	40	1	0	25.94	5.30	40.93	14.50
6	40	1	1	30.25	3.94	23.73	12.15
7	40	1	1	28.69	5.06	34.20	11.44
Total	300	7	2	191.95	53.98	238.28	82.15
Daily average	42.9	1	.28	27.42	7.71	34.04	11.73
Cow No. 4							
1	50	1	0	.06	7.94	35.34	13.88
2	45	1	0	13.31	4.00	35.66	13.41
3	45	1	0	20.44	2.44	28.50	12.84
4	45	1	0	29.00	1.65	32.61	14.31
5	45	1	0	31.00	2.30	34.25	14.45
6	45	1	1	24.63	.22	37.40	17.72
7	45	1	1	21.38	1.00	32.63	16.22
Total	320	7	2	139.82	19.55	236.39	102.83
Daily average	45.7	1	.28	19.97	2.79	33.77	14.69

TABLE D.—NITROGEN BALANCE
(All weights in grams)

Cow No.	Nitrogen in feed consumed	Nitrogen in feces	Nitrogen in urine	Nitrogen balance
Period I				
1	612	307	355	—55
2	594	261	446	—113
3	522	247	291	—16
4	603	239	378	—14
Period II				
5	617	290	274	+53
6	621	298	332	— 9
7	594	232	316	+46
8	621	267	392	—38

TABLE C. (Concluded)—DAILY COLLECTION DATA: PERIOD II

Day	Feed offered: Silage lbs.	Feed offered: Soybean oil meal lbs.	Feed offered: Salt oz.	Feed offered: Water lbs.	Orts lbs.	Feces lbs.	Urine lbs.
Cow No. 5							
1	50	1	1	15.81	.22	43.29	12.20
2	50	1	1	26.50	.44	39.75	10.19
3	50	1	1	.00	.19	35.19	19.91
4	50	1	1	44.44	.49	43.19	15.69
5	50	1	1	16.56	.22	43.19	14.31
6	50	1	1	26.94	.40	42.69	15.66
7	50	1	1	42.63	1.13	38.69	12.81
Total	350	7	7	172.88	3.09	285.99	100.77
Daily average	50	1	1	24.70	.44	40.87	14.40
Cow No. 6							
1	50	1	1	19.88	.24	44.53	9.58
2	50	1	1	28.25	.39	37.58	14.55
3	50	1	1	26.50	.42	57.00	14.84
4	50	1	1	24.69	1.24	57.33	15.53
5	50	1	1	39.69	.63	33.05	14.30
6	50	1	1	23.25	.90	56.13	13.21
7	50	1	1	46.50	.60	48.45	15.41
Total	350	7	7	208.76	4.42	334.07	97.42
Daily average	50	1	1	29.82	.63	47.73	13.92
Cow No. 7							
1	50	1	1	.00	.85	43.36	16.84
2	50	1	1	.00	1.10	31.43	13.63
3	50	1	1	26.69	3.04	23.86	11.56
4	50	1	1	20.31	3.43	31.83	18.31
5	50	1	1	21.75	7.19	39.15	11.66
6	50	1	1	.00	2.42	38.98	14.75
7	50	1	1	44.81	7.00	28.64	14.15
Total	350	7	7	113.56	25.03	237.25	100.90
Daily average	50	1	1	16.22	3.58	33.89	14.42
Cow No. 8							
1	50	1	1	24.25	.18	50.74	16.03
2	50	1	1	26.00	.19	36.56	14.03
3	50	1	1	19.00	.17	45.05	17.03
4	50	1	1	22.00	.13	37.88	18.15
5	50	1	1	26.88	.23	38.56	18.00
6	50	1	1	28.50	.21	38.90	18.47
7	50	1	1	25.63	.09	42.28	15.09
Total	350	7	7	172.26	1.20	289.97	116.80
Daily average	50	1	1	24.61	.17	41.42	16.70

TABLE E.—CALCULATION OF METABOLIZABLE ENERGY
(All measurements in therms)

Cow No.	Energy of feed consumed	Energy of feces	Energy of urine	Energy of methane	Energy correction for nitrogen balance	Total metabolizable energy
Period I						
1	203.9	83.9	8.9	15.0	−.4	96.5
2	176.8	76.9	9.0	11.8	−.8	79.9
3	148.1	67.4	7.1	10.6	−.1	63.1
4	180.1	70.7	8.8	13.5	−.1	87.2
Period II						
5	181.2	75.5	7.7	11.8	+.4	85.8
6	180.9	76.8	7.6	11.6	−.1	85.0
7	170.8	68.3	10.1	11.8	+.3	80.3
8	182.4	73.6	8.9	12.4	−.3	87.8

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